A Prospective study of

ANALYSIS OF THE TREATMENT OF INFECTED NONUNION OF LONG BONES USING MONOLATERAL EXTERNAL FIXATOR

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CERTIFICATE

This is to certify that this dissertation in **"ANALYSIS OF THE TREATMENT OF INFECTED NONUNION OF LONG BONES USING MONOLATERAL EXTERNAL FIXATOR"** is a work done by **Dr. VIJAYANAND THAMBIAH, M.** under my guidance during the period 2003-2006. This has been submitted in partial fulfillment of the award of M.S.Degree in **Orthopaedic Surgery (Branch-II)** by the Tamilnadu Dr. M.G.R. Medical University, Chennai.

Prof. Dr. A. SIVAKUMAR, M.S (Ortho), D.Ortho.,
Professor and Head of The Department,
Department of Orthopaedics,
Govt. Royapettah Hospital & Govt. Kilpauk Medical College,
Chennai.

THE DEAN
Government Kilpauk Medical College
Chennai.

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Analysis of the treatment of infected non-union of long Bones using monolateral External fixator

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INTRODUCTION

Ununited fractures of long bones are not only a complex surgical problem but also a chronic and at times debilitating condition. Infected nonunion of long bones are not only a source of functional disability but also can lead to economic hardship and loss of self-esteem. Infected nonunion[13, 32] has been defined as a state of **failure of union for 6 to 8 months** with **persistent infection** at the fracture site.

Infected nonunion can develop after an **open fracture**, after a previous open reduction and internal fixation **(ORIF),** or as sequelae to chronic **hematogenous osteomyelitis**. The incidence also seems to be increasing especially in view of increasing high velocity trauma, which is more frequently treated with internal fixation.

It is difficult to treat infected nonunion[7, 13,44] because of the following reasons.

1. **Previous surgeries** would have resulted in cicatrisation of the soft tissue with an avascular environment around the fracture site.
2. The **sinus tract** formation leading on to the fracture site indicating dead bone or sequestrum inside.

3. **Necrosis of bone** near the nonunion site, to a considerable distance, due to thrombosis of blood vessels of Haversian canals.
4. **Prolonged immobilization**, multiple surgeries with fibrosis of the muscles leading on to a stiff joint/fracture disease.
5. **The microorganism** may develop resistance to the antibiotic therapy and poses a problem in controlling the disease.

Soft tissue loss with multiple sinuses[25, 15], osteomyelitis, osteoporosis, complex deformities with limb length inequality, stiffness of the adjacent joints and multi drug resistant infection all complicate treatment and recovery. These factors make an unfavorable milieu for fracture union. Even after prolonged treatment and repeated surgeries to correct this problem, the outcome is unsure and amputation may be the only alternative left.

Hence the treatment of Non-union of long bones associated with infection is a formidable challenge to the orthopaedic surgeon. Bone union is not usually obtained until the **infection** has been eradicated. The method known as the **distraction osteogenesis**[25] simultaneously

addresses deformity, shortening, loss of bone function, osteoporosis and soft tissue atrophy.

There are various modalities of treatment for infected nonunion. In the past there were several authors who put their mind in solving this problem by many methods where in all the factors of nonunion like deformity, shortening, infection and abnormal mobility were managed. The cornerstones for successful bone healing are **Biomechanical stability** and **biological vitality** of the bone, as they provide an environment in which new bone can be formed. According to AO manual [44], **External fixator is considered as the standard method of fixation in infected nonunion**. Internal fixation is deferred in case of infected nonunion for the fear of persistence/recurrence of infection.

The **dynamic external fixator system** is a unilateral external fixator system. With the frequent association of infection; bone defect, limb shortening, deformity and soft tissue problems with atrophic non-union makes **external fixator an attractive option for skeletal stabilization.**

AIM OF STUDY

The aim of the study is to analyze the outcome of treatment of infected Nonunion of long bones using **Monolateral external fixator (The dynamic external fixation system and Rail fixation system),** and to reveal its real usefulness.

A. HISTORICAL REVIEW

In 1853 **Malgaigne** described a simple unilateral external fixator frame.

In 1893 **Keetley**, noting the frequency of malunion in femur, recommended that rigid pins for external fixator.

Parkhill in 1897 described the use of two half pins above and two half pins below the fracture in long bones.

In 1900, **Codevilla** published the first result of a method of elongation of lower extremity.

Lambotte in 1912 and **Humphry** in 1917 were the first to advocate the use of threaded pins.

In 1931 **Pitkin** and **Blackfield** were the first to advocate pins inserted through both cortices.

Anderson and **O'Neil** of Seattle, during the period from 1933 to 1945 presented a series of papers concerning the use of half pins in leg lengthening procedures.

In 1936,**Anderson** reported on his experience in femoral lengthening.

Phemister 1n 1947 used on lay bone graft for treating nonunion

From 1938 to 1954 **Hoffman** of Switzerland presented a series of articles describing his method of external fixation, his reports brought an upsurge in the popularity of external fixators.

The concept of segmental transport by distraction osteogenesis has been credited to **Sir G.A.Ilizarov** (1951- 1970), a Russian surgeon who through his research in soft tissue and bone regeneration has filled large segmental defects.

Prof. Ilizarov's[1] methodology marks the beginning of a new scientific and practical concept, which has allowed the evaluation of new, previously unknown biological laws regarding bone transmission, osteo induction and tissue neogenesis. Even in the presence of infection his technique was used. It was not until the 1970s that rigid external fixation received wide recognition in United States.

Green, one of the pioneer in this subjects of nonunion has applied the principles of distraction osteogenesis in the management of infected nonunion in United States.

Even though the unilateral external fixator is simple, the lack of versatility in the correction of mutiplanar deformities and large bone defects, resulted in the invention of much stronger and versatile external fixator, the **ORTHOFIX at Bussolengo, Verona. Italy**[6, 17].

B. CAUSES AND CLASSIFICATION OF NON-UNION

CAUSES:

In 1986 **FDA** panel defined nonunion[7, 13,44] as “established when a minimum of nine months have elapsed since injury and the fracture show no visible progressive signs of healing for 3 months.” But this criterion cannot be applied to every fracture. A fracture of shaft of long bones should not be considered as nonunion until at least **6 months** after the injury, because often union requires more time, especially after some local complication such as an infection.

Non-union can result from the following causes [7,13,44]:

1. Excess motion

    Due to inadequate immobilization

2. Gap between fragments

   a. Soft tissue interposition

   b. Malposition or overriding or displacement of fragments

   c. Loss of bone substance

   d. Distraction by hardware or traction

3. Loss of blood supply

   a. Damage to nutrient vessels

   b. Excessive stripping or injury to periosteum and muscles

   c. Free fragment, severe comminution

4. Infection

   a. Bone death (sequestrum)

   b. Osteolysis (Gap)

   c. Loosening of implants

5.General (pre disposing factors)

   Age, Nutrition, Steroids, Radiation, Anticoagulants etc.,

CLASSIFICATIONS

There are various classifications available for nonunion and infected nonunion in the literature.

I. Judet, Muller, Weber and Cech [1,7,13,46] classified nonunion broadly into two types, they are

1.**Hypervascular** (Hypertrophic), the ends of the fragments are capable of biological reaction.

2.**Avascular** (Atrophic), the ends of the fragments are inert and incapable of biological reaction.

Hyper vascular/Viable/Hypertrophic nonunion further subdivided into

1. Elephant Foot type
2. Horse hoof type
3. Oligotrophic type

Avascular/Nonviable/Atrophic nonunion further subdivided into

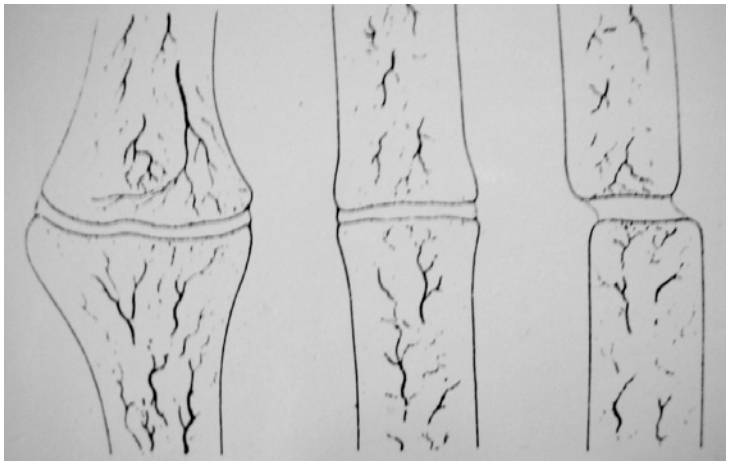
1. Torsion wedge
2. Comminuted
3. Defect
4. Atrophic

The above classification based on viability of the fracture ends with or without infection is a radiological classification.

Types of Hyper Vascular Nonunion:

(A) “Elephant foot” nonunion
(B) “Horse hoof” nonunion
(C) “Oligotrophic” nonunion

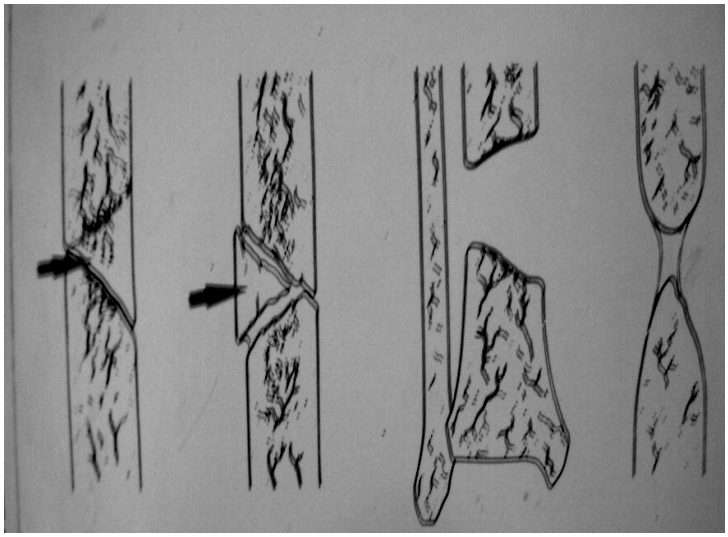
(A) (B) (C)



Types of Avascular Nonunion:

(A) “Torsion wedge” nonunion
(B) “Comminuted” nonunion
(C) “Defect” nonunion
(D) “Atrophic” nonunion

(A) (B) (C) (D)



II. Paley et al [1,7,13] divided non-union clinically and radiologically into two major types

Type A (Bone loss <1 cm)

A1- Nonunion with a mobile deformity

A2- Nonunion with a fixed deformity

A2-1 A stiff non union without deformity

A2-2 A stiff nonunion with a fixed deformity

Type B (Bone loss>1 cm)

B1-Nonunion with a bony defect

B2-Nonunion with loss of bone length

B3-Nonunion with bony defect and loss of bone length

This classification system is further modified by the presence or absence of infection.

III. Maurizio Catagni's classification [1, 46]

A1-Noninfected mobile nonunion

A2-Noninfected stiff hypertrophic nonunion without deformity

A3- Noninfected Hypertrophic nonunion with deformity

B1-Noninfective nonunion with bone defect of up to 5 cms

B2-Noninfective nonunion with bone defect exceeding 5 cms

B3-Noninfective nonunion exceeding 10 cms with local scarring

C1-Infected nonunion with atrophy

C2-Infected nonunion with hypertrophy without deformity

C3-Infected nonunion with hypertrophy and deformity

C4-Infected nonunion with bone gap of less than 5 cms

C5-Infected nonunion with bone gap between 5 and 10 cms

C6-Infected nonunion with bone gap exceeding 10 cms

IV. THE UNIVERSITY OF TEXAS CLASSIFICATION [46]

Based on the location of infection and modified by immune competence of the host:

Type 1: Intramedullary

Type 2: Superficial

Type 3: Local

Type 4: Diffuse with segmental bone loss

Type A: Healthy immune system

Type B: Local / Systemic compromise of immune system

Type C: Severe compromise of immune system

V. WIELAND CLASSIFICATION [46]

Type 1: Bone Exposed and soft tissue infection present

Type 2: Circumferential cortical and endosteal infection present

Type 3: Cortical and endosteal infection combined with segmental bone loss

VI. AO CLASSIFICATION[15, 44, 46]

1.Infected non-draining nonunion. (Active/Quiescent)

2.Infected draining nonunion.

To rationalize the treatment and for simplification we followed the AO classification in our study.

ETIO-PATHOGENESIS OF INFECTED HARDWARE[7, 13,44] :

Bacteria react to the host's attempts at eradication by releasing various virulent factors. **Glycocalyx** (slime), a hydrated mucopolysacharide, covers avascular material for example metal implant/sequestrum. This slime protects the bacteria in a sessile state increasing their resistance to destruction by a factor of 500.This layer

protects the bacteria from the effects of antibiotics, antibodies and immune directed phagocytosis.

OSTEOMYELITIS AFTER PLATING:

When tissue handling during exposure and fracture reduction is poor, with unnecessary **stripping of periosteum** at the fracture focus, additional damage to the vascularity of bone fragments will occur. If a **contamination** leads to infection, this will spread along the surface of the implants and exposed bones especially if instability develops. Necrotic and infected bone fragments will eventually be demarcated and sequestrated with further loss of stability.

OSTEOMYELITIS AFTER NAILING:

Mostly follows open nailing, in open nailing with surgical exposure of the fracture focus, additional **periosteal stripping**, loss of bone dust and potential contamination must be taken into account. Dull reamers and too large reamers can produce excessive heat and necrosis in turn can jeopardize the **endosteal blood supply**.

PINTRACT OSTEOMYELITIS:

Heat necrosis of the cortical bone occurs after drilling with blunt drill bits at excessive speed and power. Necrotic bone area may also result from forced insertion of schanz screw or steinmann pins into inadequate holes or without predrilling. Necrotic fragments in the form of **ring sequestrum** provide an excellent medium for bacteria, which migrate along the percutaneously inserted implant into the wound. Bone resorption can be seen on X-ray, which is a sure sign of pin loosening. Occasionally chronic osteomyelitis reaching into the medullary canal may develop.

C. PRINCIPLES OF MANAGEMENT

1.ERADICATE INFECTION [7,13,44]:

The principles of treatment of infected nonunion begins with **removal of all foreign material** (eg.metal) and infected necrotic bone **(sequestrum).** Fracture ends should be cut in such a way to increase the surface area of the opposing bone ends. The repairing process begins by restimulating a local inflammatory response. Administration of appropriate **antibiotics** to eradicate infection is supplement to surgery.

2.MAXIMIZE JOINT MOTION:

Second objective is to mobilize the joint to avoid **contracture and arthrofibrosis**. This was well planned by the **physiotherapy** exercises, which was advised to the patient in the post-operative period.

3.CORRECT DEFORMITY AND LIMB LENGTH DISCREPANCY:

Minimal deformity can be corrected by taking appropriate wedge at the time of debridement. Shortening in upper limb can be

acceptable, but in lower limb shortening **beyond 2.5 cms** should be corrected by **bone lengthening** procedure to have an improved gait post operatively.

4.ACHIEVE UNION:

The fourth objective is to achieve union in a reasonable amount of time both at the nonunion site and the corticotomy site. The **distraction compression osteosynthesis** increases the blood supply of the whole limb as well as the fracture site, which is advantageous for union. **Compression** produces local necrosis in the fibro cartilaginous tissue and inflammatory reaction that will stimulate the bone healing process.

D.DISTRACTION OSTEOGENESIS

Distraction osteogenesis [1] is the mechanical induction of new bone between bony surfaces that are gradually pulled apart. Distraction osteogenesis is a process initiated by the application of **tension stress** across the **corticotomy** site. There are two parameters known to affect the process of distraction osteogenesis.

1.BIOLOGICAL FACTORS

This includes the **type of osteotomy, its level and latency period before distraction.**

2.MECHANICAL FACTORS

These are known to be important, which include **stability of fixation, rate and rhythm of distraction.**

Instability will cause a wandering type of regenerate bone formation and too rigid type of construct may lead to delay in consolidation.

BIOLOGY OF DISTRACTION OSTEOGENESIS:

During distraction, a fibro vascular interface is arranged **parallel** to the direction of the distraction while new bone columns add length to the gap. When biology and mechanical conditions during distraction are ideal, bone is formed by **intramembranous ossification.**

HISTOLOGY:

Biopsies were taken from mid-sagital plane along the tibial crest of the experimental animal. A Bronwill saw was used to section the bones. Back-scattered scanning electron microscopy confirmed micro radiographic measurements with three-dimensional orientation and localized calcium deposits by microprobe analysis.

Early specimen came from **day 7 of distraction at a rate of 1 mm per day and a rhythm of 0.25 mm four times a day.** At this point of time, a fibro vascular network bridged the distraction gap. There was no evidence of mineralization.

Large vascular channels surrounded each micro-cone of bone on all surfaces. These vessels contained a thin lining of endothelial cells, with internal diameters up to 400 microns.

VASCULAR STUDIES:

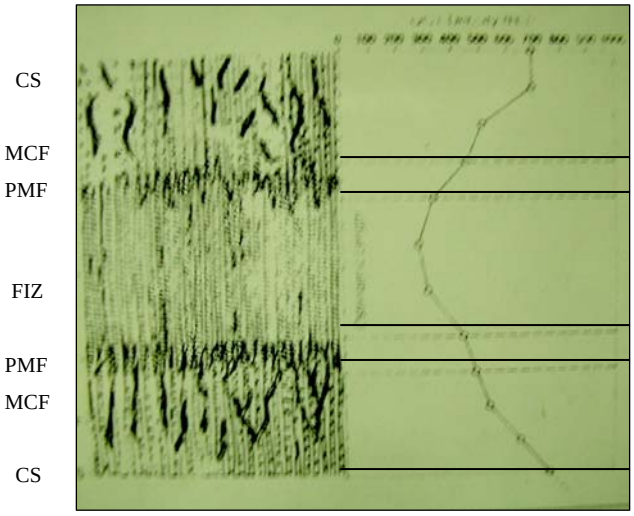
India ink injection at sacrifice on day 35 demonstrated both afferent and efferent vessels across the osteogenic area. In coronal section very few vessels crossed the fibrous interzone. The vessels were clearly oriented **parallel** to the distraction force and the new columns of bone. Technetium scintigraphy provided in vivo measurements of blood flow and bone formation related to normal zone in the experimental models.

MINERAL DENSITY STUDIES:

Plain radiograph was adequate for documenting the weekly changes in bone alignment and gap formation during distraction. The bridging of the osteogenic area and remodeling of the bony macrostructures into cortex and medullary canal was assessed in **quantitative computer tomography (Q.C.T)** clearly demonstrated the volume of mineralization within osteogenic area proceeded visualization by plain radiography.

DISTRACTION OSTEOGENESIS:

SCHEMATIC DIAGRAM OF HISTOLOGY



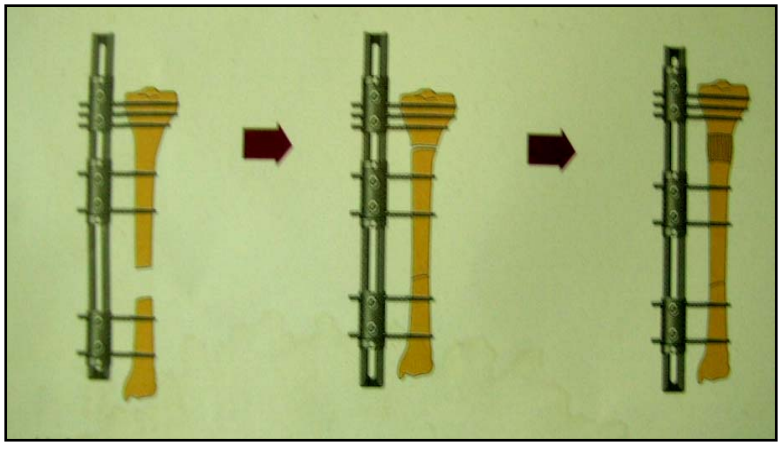
DIFFERENT ZONES DEMONSTRATED HISTOLOGICALLY AND BY QCT STUDY.

FIZ- Fibrous Inter Zone

PMF-Primary Mineralization Front

MCF-Micro column Formation

SCHEMATIC DIAGRAM



(A) (B) (C)

A. Small distal defect with shortening

B. Immediate compression distally; Proximal osteotomy

C. Proximal distraction (Lengthening)

Calcium quantification was done by 2 mm transverse section taken through osteogenic area correlated with each corresponding QCT cut.

MECHANICAL FACTORS:

The rate of distraction should remain within a range of **1 mm per day**. Slower rates allow normal fracture healing to proceed and prematurely bridge the gap. Faster rates seem to out strip advancing blood supply inhibiting mineralization.

Rhythm is defined by the number of actual distractions each day. Adequate osteogenesis occurred at the rhythm of 0.25 mm every 6 hours. At one millimeter once daily osteogenesis is significantly inhibited.

Latency is the time period between the operation and the initiation of distraction. The average recommended **latency** is from **4 to 7 days**. Osteogenesis may proceed in an angular fashion, but the angles may be unintended.

Jorge.E.Alonso and **Pietro Regazzoni** have divided the treatment period into three phases.

TRANSPORT PHASE:

This phase is the period from the initial advancement of the segmental defect until the end of the transport, when the segment transport contacts the other fragment **(Docking)**

Ilizarov has demonstrated that **intra membranous ossification** occurs during distraction.

MATURATION PHASE:

During this phase an increase in the **mineral content** of the regenerate area can be seen. The quality of regenerate can probably be improved by soft tissue coverage of the open areas with rotational or free vascular flaps.

CONSOLIDATION PHASE:

This is a **compression phase**, during which the **cortical bone** content increases to about **80%.** Once the segment reached the distal fragment, the interphase can be improved by methods like plating and cancellous auto grafting to reduce duration of consolidation phase.

E.BIOMECHANICS OF ORTHOFIX SYSTEM

In monolateral external fixator system bone grip is achieved optimally using half pins. The orthofix screw is made of **AISI 316L ESR stainless steel** [17]. A practically impurity-free alloy is obtained by electros lag refusion. The steel is also subjected to a cold surface hardening deformation process that increases its yield strength from 50 da N-mm $^{-2}$ to80 da N.mm^{-2}.This material shows excellent resistance to yield loads.

The pitch is essentially determined by the prevalent type of bone tissue in which the screw is inserted. The pins designed for **cortical bone had a pitch of 1.75mm,**and **for cancellous bone had a pitch of 3mm**.The correct relationship between drill and screw diameters, and the profile of the thread of the screw help to reduce thermal damage when the screw is inserted, and improve the mechanical properties of the construct. The most suitable drill diameter for **cortical screw is 4.8mm** and **cancellous screw 3.2mm**.Pins tapered **6to 5mm is suitable for femur and tibia, pins tapered 4.5 to 3.5mm is suitable for humerus.**

Wikenheiser et al [17] compared the thermal effects of screws and came to a conclusion that the **tapered ORTHOFIX screw** generated the lowest temperature, always below the limit of **50 degree C.** (considered the highest permitted temperature to avoid thermal necrosis)

TAPERED BONE SCREWS [17]

Tapered Bone Screws are "Designed for **Increased Holding Power**".

The integrity of the pin-bone interface is vital to the success of external fixation; pin loosening must therefore be avoided.

The mechanisms of **pin loosening** are:

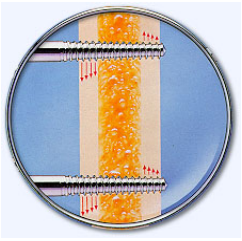
Screw bending

Unequal loading

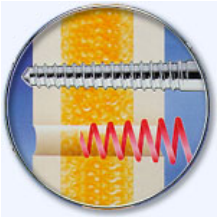
Pre-tensioning

Pin track infection

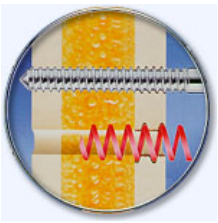
This leads to lysis causing enlarged pinholes followed by . . . Pin loosening. The features of the Orthofix tapered screw contribute to better purchase in the bone and for stable fixation.



Tapered screw offers Higher resistance to bending where it is most needed i.e., at the near cortex With a unilateral fixator**, 60-70% of the load is exerted on the near cortex**, (data on file). The greater screw diameter at the near cortex ensures a higher resistance to bending.



During insertion, each screw thread cuts a new, **slightly larger path** in the bone. Pre-drilling reduces the forces required for screw insertion and ensures an even load distribution. The screw design thread geometry produces efficient radial purchase. These design features combine to provide excellent bone purchase. In addition, it has been shown that the act of **dynamization** itself - which is central to the Orthofix philosophy of fracture repair – reduces the stress on the screws and further enhances the security of screw fixation [17,49]. The disadvantage lies in the fact that the **screw cannot be backed up even partially,** because, if it is done, bone grip will be lost totally.



The '**Non-Orthofix**' uniform diameter screw – During insertion each successive screw thread occupies

grooves cut in the bone by the previous threads. This results in repeated and **sustained erosion of the grooves**. When the far cortex is encountered, difficulty may occur in penetrating the bone. The surgeon supplies additional force to insert the screw and the rapid insertion may cause the screw to advance into the bone like a **wedge and rupture the cortex.**

Purchase may also be less than ideal, since the **flute interrupts continuity** of the thread. At the near cortex, the force required for screw insertion may cause damage to the grooves already cut, and the screw entry hole is enlarged. These design features may cause **uneven load distribution and pin loosening.**

Other benefits associated with the Orthofix tapered screws; they can be removed painlessly and easily in the outpatient department. The tapered pins are easy to remove[9] in the clinic **because all of the threads become loose after the initial turn.**

Orthofix provides:

The widest possible range of screw type and sized including cortical screws, cancellous screws and "cutting edge" screws for lengthening

and bone transport procedures. Instrumentation designed to ensure a precise and standardized screw introduction technique with minimal trauma to associated soft tissue structures. In **osteoporotic** bone **Hydroxyapatite** coated[33] pins can be used, which has the ability to improve the interface between bone and metal implant. A comprehensive **postoperative pin-care** protocol for the maintenance of trouble-free pin sites is an essential ingredient for the success of any external fixation procedure.

The **soft tissue tension** should be avoided to minimize pin tract infection at the time of pin placement. The fundamental principle[5, 31] for pin placement especially when distraction osteogenesis is attempted is that the pins that are placed at each end of the long bone should be parallel to the adjacent joint in all planes. The nuts on the orthofix apparatus are tightened with a **torque wrench** (Allen key) that is provided.

REUSAGE[49]:

The apparatus consists of various clamps, which are **hard anodized** on

Aluminium alloy. Once the apparatus has been completely used, the entire apparatus is dissembled; the tapered half pins are discarded, since they should not be reused. Once the integrity of the apparatus is confirmed the dissembled parts are immersed in 36 volume of **Hydrogen peroxide** for more than 12 hrs, any residue remaining are brushed in running water, then soaped in distilled water, as this will remove traces of hard water. After the above treatment the apparatus is dried and sent for re-sterilization for the next usage. (Instructions from the manufacturer of the apparatus should be followed)

THE ORTHOFIX AND THE LIMB RECONSTRUCTION SYSTEM (LRS)

Experimental data as well as clinical studies have shown us that same effect can be obtained with many fixators. Whenever possible the assembly should **technically be easy and comfortable** to the patient. Unilateral fixators meet these prerequisites. The advantage of the monolateral dynamic axial system is that it is a **modular** concept, which allows different constructs from simple to complex assembly. **Preoperative planning** of screw placement, corticotomy site, and fixator

orientation is necessary. The fixator is applied following the principles of application of external fixator.

The **LRS (Limb Reconstruction System)** consists of **rails**[40] of 240mm, 300mm, 400mm,to which **multiple sliding screw clamps** are attached, one clamp per segment of bone. Straight longitudinal clamps with longitudinal screw clusters are used unless small metaphyseal segments require fixation, in which case a **T-clamp** for **transverse screw orientation** is used. The rail must be parallel to the bone that is stabilized with accurate bone alignment. To achieve this care must be taken in applying the most **distal and proximal screws** because once these are applied, subsequent adjustments in limb alignment are not possible. If these two screws are both applied **perpendicular to the axis of the bone**, the rail ends up parallel with the bone, and accurate limb alignment, bone transport, and eventual docking are ensured [40].

The location of the most proximal and the distal screws depends on the location of the defect and the planned corticotomy site. For proximal tibial corticotomies, the first screw should be in the flare of the proximal tibial metaphysis. When the second screw is inserted

rotational alignment must be correct. At the time of application of the screw, the middle clamp's position should be verified. **Bicortical purchase** of all screws must be verified. After all screws are placed, the **template clamps** are replaced by the definitive fixator clamps, and the LRS is tightened into place.

INDICATIONS:

The device can be used for the following indications

1. Fracture fixation.
2. For correcting diaphyseal/metaphyseal deformities with or without shortening.
3. Correction of bony or soft tissue deformities.
4. Limb lengthening.
5. For treating nonunion and malunions.
6. Bone transport application.

CONTRAINDICATIONS:

1.Severe Angulations and deformities, which can be better treated by Ilizarov.

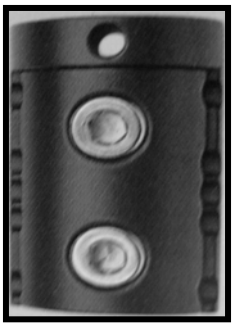
2. Severe osteoporosis.

3.Patients in whom cooperation is lacking thereby reducing patient compliance.

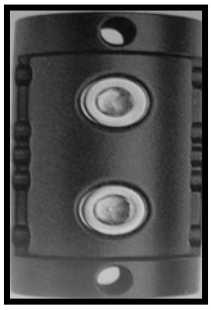
Preliminary frame assembly is recommended to reduce the operative time and to assure an adequate supply of components before surgery. Appropriate size of rail, clamps, tapered half pins and drill bits are selected. **Tapered half pins** should be in strict anatomical consideration avoiding damage to nerves and vessels. The tapered half pins should be gently pushed through the soft tissue, not drilled. All components are tightened or fastened with appropriate instruments. The same principles have been applied in the **Indian version of orthofix** system namely the **Dynamic External fixation system** and the **Rail Fixation System.**

SOME OF THE PARTS OF THE FIXATOR

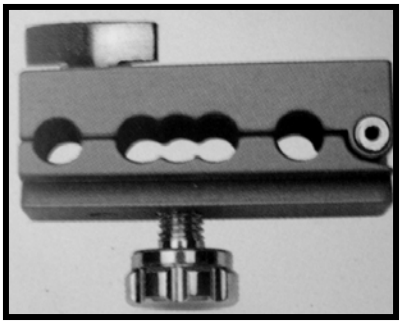
STRAIGHT OUTER CLAMP



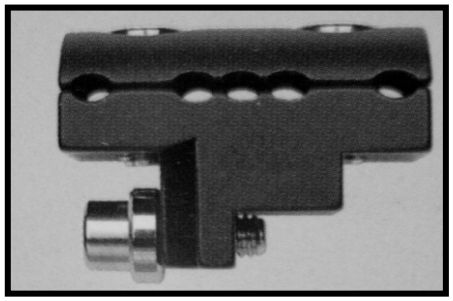
STRAIGHT CENTRAL CLAMP



TEMPLATE FOR STRAIGHT CLAMP

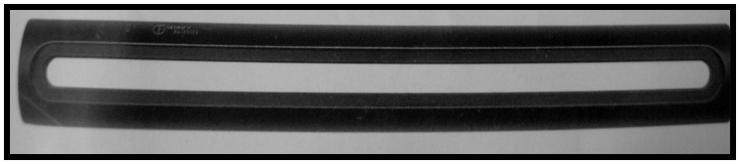


T-CLAMP

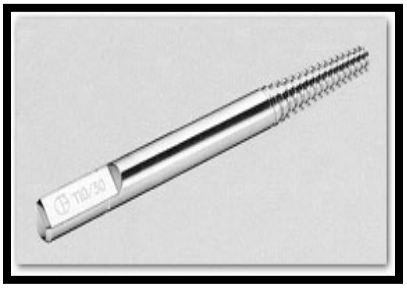


DISTRACTION COMPRESSION UNIT

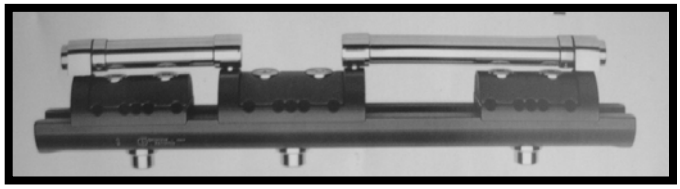
RAIL



TAPPERED BONE SCREW



FIXATOR ASSEMBLED



MATERIALS AND METHODS

MATERIALS:

This is a **prospective** study conducted at Govt. Royapettah hospital and K.M.C., which consists of **21 cases** in the age range from 16 yrs to 65 yrs (with a mean age of 37.5 yrs.) who were treated at our institution from July 2003 to Feb 2006.Patients who were lost to follow up were not included in this study. Our institution approved our treatment protocols and all patients gave written informed consent. There were **18 males and 3 females** in our study with male to female ratio of 6:1.

These infected nonunion were classified by the AO classification[15, 44]. In our study, According to this classification we had

Infected quiescent non- draining nonunion – 4 cases

Infected active non-draining nonunion – 3 cases

Infected draining nonunion –14 cases.

Patients with wounds that had no discharge for **3 months** were labeled as non-draining **(Quiescent)**. Infection was evident by local symptoms and signs like increase warmth, redness, sinus, fever, etc,.

12 patients had infected nonunion of **femur**, **7** patients had infected nonunion of **tibia** and **2** patients had infected nonunion of **humerus**.

Of the **12 cases of femur**, 5 had infected nonunion after ORIF with nail/pate for closed fractures, 5 had infected nonunion which occurred after open fractures and subsequent native treatment, and 2 had infected nonunion following treatment of open fracture with AO external fixator system.

Among the **7 cases of tibia**, 3 patients had infected nonunion after ORIF for closed fracture, 4 infected nonunion occurred after open fracture.5 patients had infected draining nonunion and 2 had infected quiescent non-draining nonunion.2 patients with septic non union of humerus resulted after ORIF with plating for closed fractures. Our **follow up** period was with a maximum of **28 months to a minimum of 6 months (mean 16.8 months)**. The bone involved and the type of

nonunion, along with the number of cases and age distribution are given in table 1,2,3,4.In Toto, of the 21 cases, infected nonunion resulted from **previous surgeries** in 13 cases. In 6 cases infected nonunion resulted from improper treatment of the **open fracture** by native bone setters and in 2 other cases infected nonunion resulted after **cast immobilization** for Grade 1 open fracture (Gustillo Anderson classification).

Diagnosis was established by history physical examination and investigations like erythrocyte sedimentation, total and differential white blood cell count pus culture sensitivity and standard AP, LATERAL X-rays. History is taken from the patient including the date of injury, detail of original accident and subsequent treatment. Special attention was focused on limb length measurements, range of motion of the joints, neuromuscular status and distal vascularity. **8 cases** of infected non-union had **knee stiffness**, **6 cases** had **ankle stiffness.**

DISTRIBUTION OF NONUNION IN VARIOUS BONES IN OUR STUDY

TABLE -1:

DISTRIBUTION OF NONUNION	NO.OF CASES
FEMUR	12 CASES
TIBIA	7 CASES
HUMERUS	2 CASES

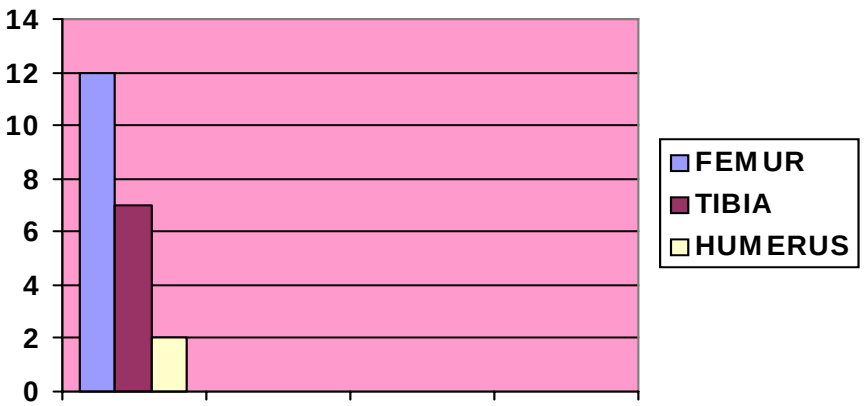
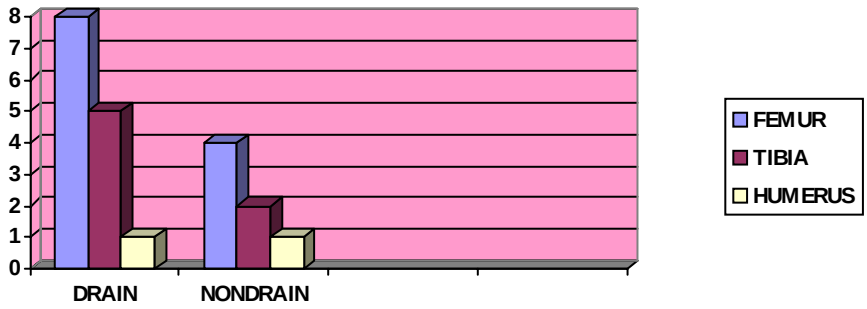


TABLE -2:

BONE	DRAINING NONUNION	NON DRAINING NONUNION
FEMUR	8 CASES	4 CASES
TIBIA	5 CASES	2 CASES
HUMERUS	1 CASE	1 CASE



SEX DISTRIBUTION

18 MALES AND 3 FEMALES

TABLE-3:

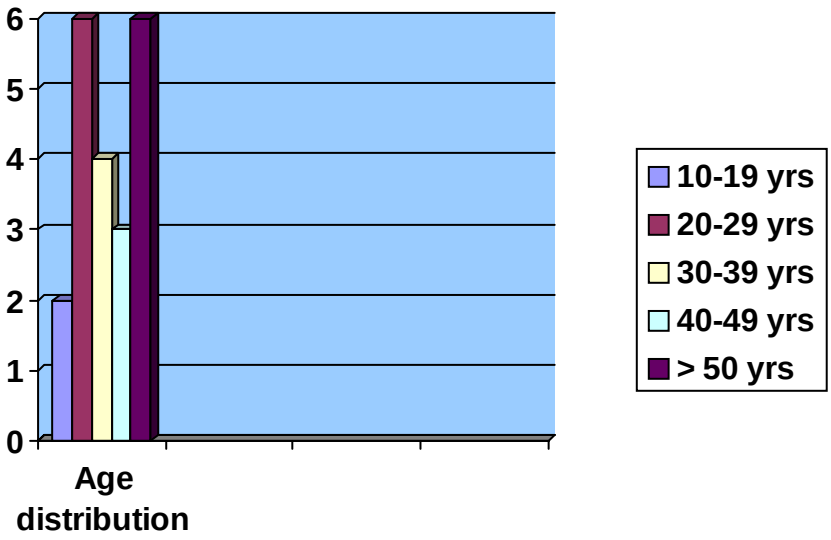
Previous treatment received by the patients

INFECTED NONUNION	TOTAL	PLASTER (POP)	EXTERNAL FIXATION	PLATING	NAILING	NATIVE TREATMENT
FEMUR	12	-	2	2	3	5
TIBIA	7	2	1	-	3	1
HUMERUS	2	-	-	2	-	-

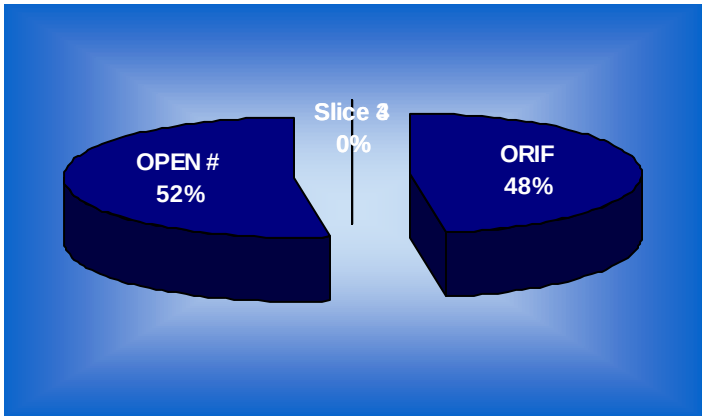
TABLE 4:

AGE DISTRIBUTION:

10-19 YRS	2 CASES
20-29 YRS	6 CASES
30-39 YRS	4 CASES
40-49 YRS	3 CASES
ABOVE 50 YRS	6 CASES



INFECTED NONUNION DEVELOPMENT AFTER ORIF/OPEN # (10/11):



METHODS:

The cost of the original **orthofix is high**. The price is beyond the reach of our patients. Various **Indian versions** of Orthofix have been introduced in the recent past, which is much cheaper than the original and is available at an affordable price for the patients. We did not come across gross deformity as most of the cases in our study have had previous surgeries and the problem was mainly infected nonunion with minimal deformity.

The most common organism isolated from draining non-union was staphylococcus, other than that pseudomonas, proteus, klebsiella were also isolated in different cases. Fortunately we did not come across **MRSA** (Methicillin resistant Staph. Aureus) infection. Based on the culture report specific antibiotics were chosen and given to patients. Antibiotics have always been considered as complementary to surgery.

SURGICAL PROTOCOL:

ANAESTHESIA:

For **upper limb**, the surgery was performed under **general anaesthesia** and for the **lower limb** the surgery was performed under **spinal anaesthesia.**

The appropriate parenteral **antibiotics**, which the patient has been taking preoperatively for infection, are administered before the start of the surgery and continued post operatively.

Through **previous scar** if surgery has been done already, metal exit (10 cases) was done, through wound debridement and excision of the infected soft tissue and necrotic bone till fresh bleeding appeared **(Paprika sign.)**[39], was done. The sinus tract, infected soft tissue, and unhealthy granulation tissue was excised and sent for **histopathological and culture study.**

The **medullary canal** was opened on either side by gentle reaming. **Monolateral external fixator** was applied following this. The **most distal and the proximal** screws were applied first and tightened after making sure that the limb is in proper alignment and rotation, remaining screws were passed subsequently. In all the cases acute **docking** was done at the **nonunion** site and **compression** given. The

operative field was thoroughly irrigated and wound closed by stay sutures. In some of the cases **drain** was kept, which was removed after **48 hrs.**

In two cases there was **wound dehiscence**, which healed after **skin grafting** after the formation of healthy granulation tissue. In five of our cases were the shortening was from 3 to 5 cms (mean 4.2 cms.) acute docking was done at the debrided site and osteotomy was performed distal to the tibial tuberosity at the **proximal metaphyseal area** for tibia (4 cases) and **distal supracondylar osteotomy** for femur (1 case) by means of separate set of instruments so as to prevent introducing infection at the osteotomy site.

An **open approach** is made to perform **corticotomy**, which is actually a low energy osteotomy made by connecting multiple through and through **drill holes** with an **osteotome**. Attention should be paid to **preserving periosteum** because it has a major role in osteogenesis. Segmental resection of **fibula** was done in leg to allow acute docking. Distraction was started on the **7 th post operative day**[1, 32]. In case of humerus nonunion the shortening that resulted from debridement was accepted [22]. In one case the shortening was 1 cm and in other it was 2 cms.

For femur the fixator was always applied[11, 44] to the **lateral aspect**, for the tibia the fixator was always applied to the **medial aspect** and for the humerus the fixator was applied to the **poterolateral aspect**. In the hospital the distraction was done by the surgeon and after discharge from the hospital this was done by the patient or his relatives.

All patients had considerable bone loss after through debridement, from **1.5 cms to 5cm (mean 3.2 cms)**. In all of the cases after debridement acute docking was done at the nonunion sites, as the maximum amount of bone loss we encountered was 5 cms. Distraction was carried on for a period of minimum 34 days to a maximum of 58 days **(mean 46.6 days).** The length of bone **gained** was from **3 to 5 cms. (Mean 4.2 cms.).** In one case of septic nonunion of femur supracondylar corticotomy was done and distraction was carried out from below upwards.

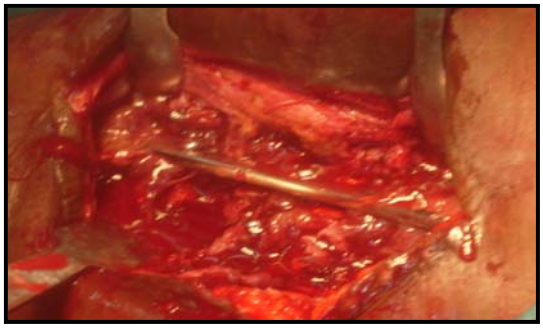
In some of the cases **supplementary procedures** like skin grafting, flap cover, revision of pins and bone grafting were carried out. In spite of through debridement and antibiotics, infection did not get controlled in 3 cases.

ORTHOFIX FIXATOR (INDIAN VERSION)

DISCHARGING SINUSES

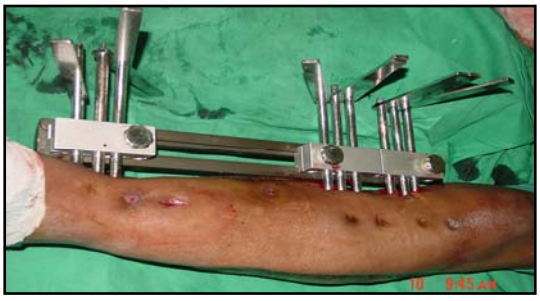
INTRA OPERATIVE PHOTOS

INFECTED PLATE-REMOVED

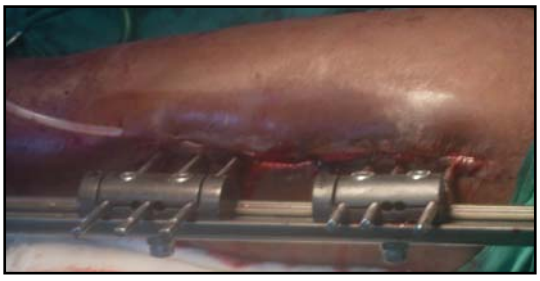


INFECTED NAIL REMOVED

TEMPLATE USED BEFORE APPLYING DEFINITIVE CLAMPS



FIXATOR IN PLACE



POST-OPERATIVE PROTOCOL:

Post operatively, the limb is kept **elevated** to reduce the post-operative edema. The **ankle** is splinted in neutral position. Drain is removed after 48 hrs. **Parenteral antibiotics** were continued for 2 weeks post operatively or till the subsidence of infection and then oral antibiotics were given for an additional 2 weeks. **Joint motion exercises** and non-weight bearing followed for 4 weeks and then partial weight bearing was advised**. Distraction** was carried at the rate of **0.25 mm four times a day, which was started from the 7 th postoperative day[1, 32]. Radiograph** was taken every week during the initial period of distraction and at monthly interval thereafter.

On discharge, all patients were taught about pin site care, hygiene and the rhythm of distraction where lengthening procedure was carried out.

The patients were followed in the out patient department, where assessment of clinical and radiological progress was made. The rate of distraction was altered based on the radiographic

appearance of the **regenerate**. In all cases compression at the nonunion site was maintained till union. **Poor consolidation** of the regenerate (2 cases) was treated by encouraging weight bearing and alternate compression –distraction (**Accordion technique**) [32]. The distraction was stopped when sufficient gain of length has been achieved. The fixator was left in position for a further period to allow **consolidation of callus**.

In two cases, in spite of successful docking and control of infection, there were no signs of radiological union; **iliac graft** was applied at the docking site. Our criteria for radiological union[22] are the presence of bony consolidation in **three out of four cortices in AP and Lateral x-rays.** When this is achieved, the patient is examined clinically and the fixator is removed. After removal of the fixator patient is advised to use **functional cast brace** for upper limb and **crutches** for lower limb for a period of 6 weeks during which the patient is gradually mobilized to full weight bearing.

RESULTS

ANALYSIS:

In the last 32 months we had the opportunity to treat **21 cases** of infected non-union with monolateral external fixator. Of the 21 patients **11 (52%)** patients developed infected nonunion following **open fracture** and 10 patients **(48%)** developed infected nonunion following previous implant surgeries for **closed fractures**. Our follow up of cases varied from **6 to 28 months (mean 16.8 months).**

Union time ranged from **4 to 9 months (mean 5.9 months).** Sinus tract got cleared in all cases except 3 where the sinus tracts were multiple and there was no progression towards union in those cases**. (Case no 18,19,15)**. There was no difficulty in this series as far as transportation of bone. There was considerable **delay** in **the consolidation phase** in all cases. Out of 21 cases 11 cases had **pin tract infection (52.3%).** For wound dehiscence in the post operative period, split skin graft cover was given in two cases.

During transportation phase in bone lengthening procedure there was pin tract infection and **loosening** in two cases for which pin revision was done. In all cases there were no infection at the corticotomy site. After a period of waiting for consolidation to occur, the final result of the healing of the osteotomy was adequate in all five cases. The cases with limb length discrepancy up to 2.5 cms in lower limb managed with **modified footwear** with **heel and sole raise**.

The results were divided into **bony results and functional results,** according to the classification of the ASAMI [1,15] (Association for the study and application of the method of Ilizarov). **ASAMI'S** criteria were used to analyze the results in our study, as there were no specific criteria available in the literature for assessing the results after treatment with orthofix fixator. Union of the **upper limb bones** is not included in this classification.

BONE RESULTS:

The bone results were determined according to **ASAMI'S criteria** as follows:

(1) Union

(2) Infection

(3) Deformity

(4) Leg length discrepancy.

The fracture was considered to be united when it appeared so roentgenographically, when there was no motion at the site of the nonunion after loosening all nuts in the apparatus and the patient was able to walk without pain and had a feeling of solidity of the limb. According to the protocol of the ASAMI[1, 15], a bone result cannot be graded excellent unless union was achieved without the use of the bone graft.

Bone union results:

E-Excellent -Union + No Infection+ Deformity<7 degrees+ Shortening<2.5cms.

G-Good - Union + any TWO of the above factors.

F –Fair -Union+ any ONE of the above factors.

P-Poor -No union/Refracture/none of the above factors.

According to these criteria the bone result in our study was

Excellent - 6 cases

Good - 8cases

Fair - 2 cases

Poor - 3 cases.

FUNCTIONAL RESULTS:

The functional results were based on **five criteria** [1,15]:

(1) A noteworthy **limp**

(2) **Stiffness** of either the knee or ankle (loss of more than 15 degrees of full extension of the knee or of 15 degrees of dorsiflexion of the ankle in comparison with the normal contra lateral side)

(3) Soft tissue **sympathetic dystrophy**

(4**) Pain** that reduced activity or disturbed sleep and

(5) **Inactivity** (unemployment or an inability to return to daily activities because of injury.)

Functional results– limp, equinus, ankle rigidity, soft tissue deformity, pain & inactivity

Excellent -active + no other

Good -active + 1 or 2

Fair - active + 3 or 4

Poor - inactive irrespective of whether other criteria were applicable.

According to these criteria the functional result was

Excellent - 3 cases

Good - 11 cases

Fair - 2 cases

Poor - 3 cases.

The functional results of the upper limb were determined by assessing pain, shoulder and elbow range of movements and strength. In the cases of infected nonunion of humerus, at follow up there was no pain/limitation of movements of elbow or shoulder and the strength was adequate.

There was no neurological or vascular injury as a result of instrumentation. The **Bone healing index** [11] (days of fixator use/centimeters of length gain) was **47.1 days/cm.**

COMPLICATIONS:

We encountered certain complications and these complications were grouped into following categories as recommended by **Paley**[11, 16].

(1) **Problems** –represent minor complications that were treated non-operatively without resorting to any anaesthesia.

(2) **Obstacles** -were complications that were resolved by operative means.

(3) **True complications**- were residual permanent deficits at the end of the treatment period.

Problems:

- **Superficial pin tract infection** was found in 11 of the 21 cases (52.3%). All superficial pin tract infection responded to intravenous or oral antibiotics, except in one case where the infection persisted.
- **Mild edema** was frequently present and got resolved after removal of fixator except in 5 cases, which persisted even after removal of fixator, such patients were advised full weight bearing with elasto-

crepe bandage in the daytime and limb elevation in the nighttime for variable period of time.

Obstacles:

- During distraction in two cases **metaphyseal pins got loosened** which were readjusted in the operation theatre.
- **Equinus** correction was done by secondary surgical procedure like Achilles lengthening in 2 cases and triple arthrodesis in 1 case.
- In two cases **iliac bone grafting** was done at the non-union site at the end of 4 months when there was insufficient evidence of bony union, to aid in union.

True complications:

- **Malunion** beyond the limits of acceptability occurred in 4 cases.
- **Persisting nonunion** of the previous nonunited site occurred in three limbs.

Case 1: 25 yrs old male presented to us with infected nonunion following ORIF with K-nail for closed femoral shaft fracture which was

done elsewhere. In our institution metal exit, debridement was done, external fixator was applied and compression given at the nonunion site. The patient did not come for regular follow up and landed up with **persistence of infection** and there were no signs of fracture union after the end of 6 months.

Case 2: Another patient had Grade III B open fracture of shaft of femur with extensive soft tissue injury. The patient was initially treated with external fixator and plastic surgery procedures were done for soft tissue cover. After 4 months of application of the external fixator there was no evidence of fracture union and there was persistent discharge from sinuses at the anterolateral aspect of the thigh. We have done a through debridement and applied Rail fixation system with compression at the nonunion site. In spite of having the frame for more than 6 months **infection persisted** there was no evidence of progression towards union at the nonunion site. Orthofix fixator was removed and Ilizarov fixator was planned for the patient.

Case 3: Grade III B open fracture of shaft of tibia with extensive soft tissue injury. The patient was initially treated with external fixator and

plastic surgery procedures were done for soft tissue coverage. Through debridement and application of external fixator with compression at the nonunion site was the procedure done by us. In spite of having the frame for more than 6 months **infection persisted** there was no evidence of progression towards union at the nonunion site.

- **Residual shortening** of lower limbs persisted in 11 out of 19 cases ranging from <1 cm to 3 cms. (Mean 2 cms.).
- **Rigidity** of either the ankle or knee persisted in 8 cases.

CLINICAL CASE: PRAVEEN 16/M (MASTER CHART- CASE NO.6)

 # SOF –RIGHT

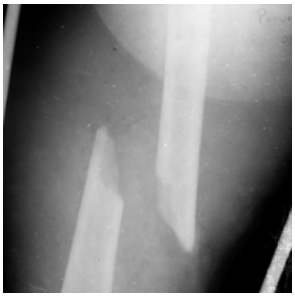
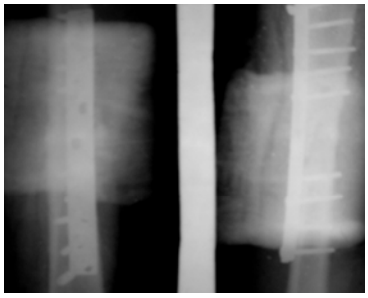
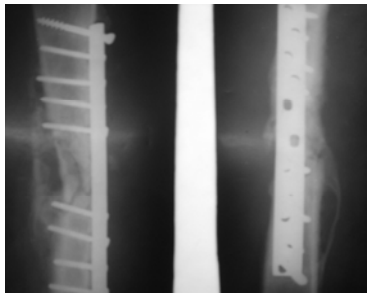


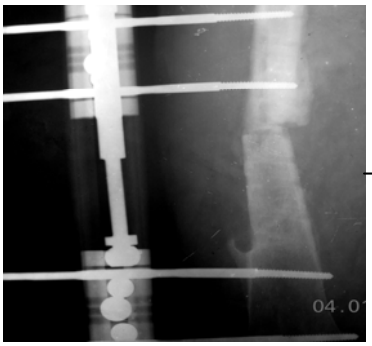
PLATE OSTEOSYNTHESIS



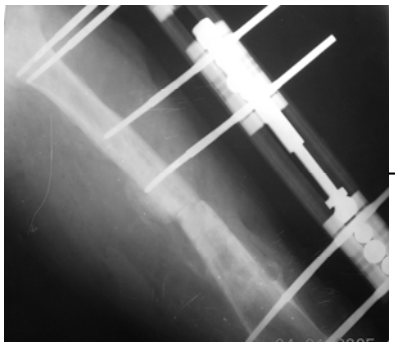
AFTER 3 MONTHS



IMMEDIATE POST-OP

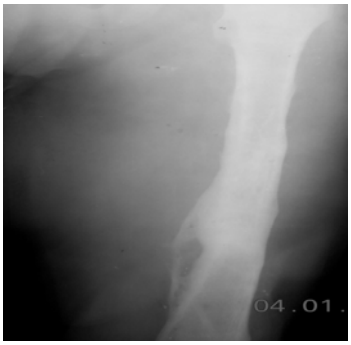


AFTER 2 MONTHS



AFTER PIN REMOVAL

AFTER 6 MONTHS



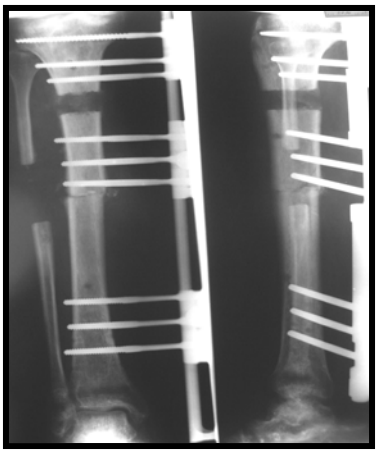
SHORTENING 2.5 CMS

GOOD ROM

CLINICAL CASE: PARTHASARATHY 54/M (MASTER CHART NO: 4)

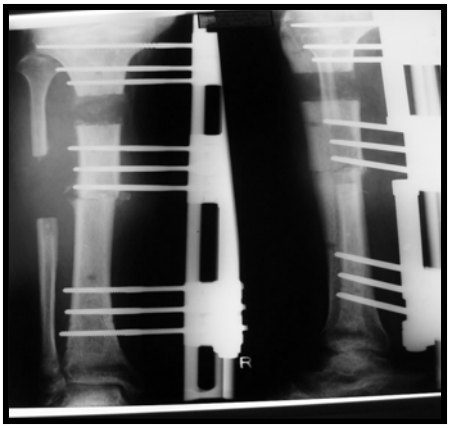
INFECTED NON-UNION

METAL EXIT, DEBRIDEMENT, DOCKING, ORTHOFIX APPLICATION, CORTICOTOMY, DISTRACTION

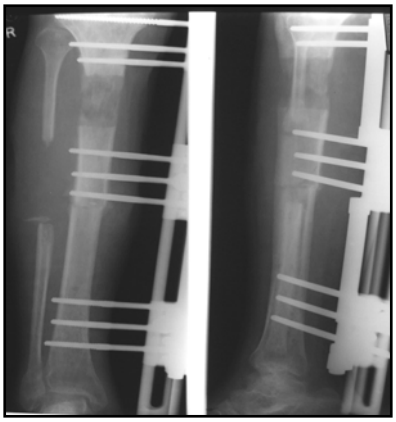


DURING DISTRACTION OSTEOGENESIS

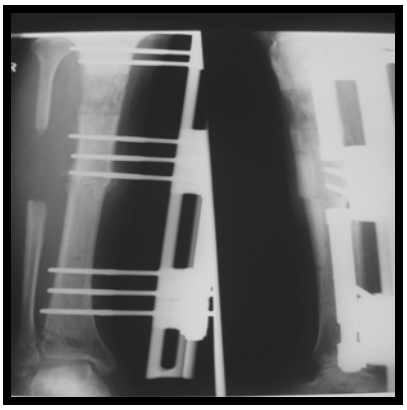
AT 4 WEEKS OF DISTRACTION



AT 8 WEEKS

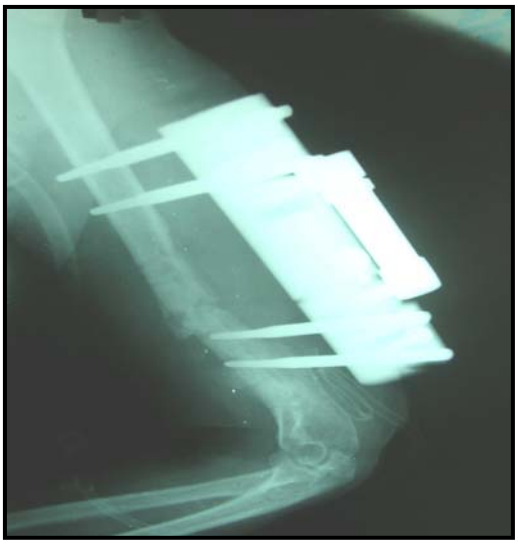


GOOD CONSOLIDATION

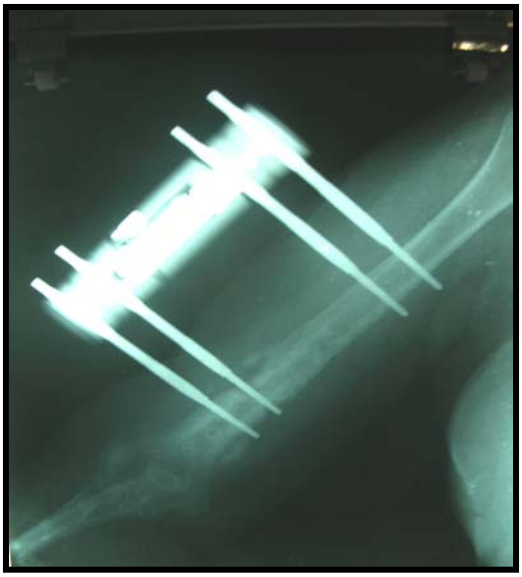


SARALA 45 F (MASTER CHART NO.17)

INFECTED NONUNION RIGHT HUMERUS, FIXATOR APPLIED AFTER DEBRIDEMENT



GOOD CONSOLIDATION AFTER 6 MONTHS

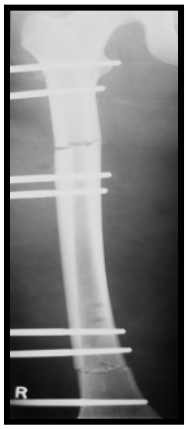


CLINICAL PHOTO

CLINICAL CASE: RAVICHANDRAN 29/M (MASTER CHART NO.9)

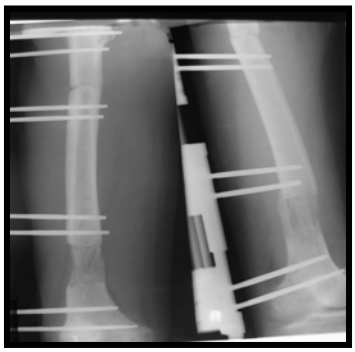
INFECTED NONUNION

DEBRIDEMENT, FIXATOR APPLIED, CORTICOTOMY
ACUTE DOCKING AT NONUNION SITE



3 WKS AFTER DISTRACTION

CONSOLIDATION AFTER 4 MONTHS

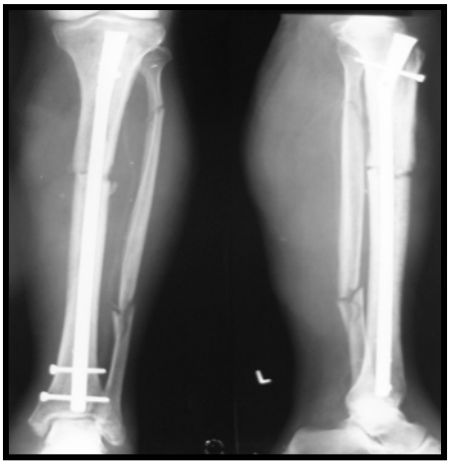


FIXATOR IN PLACE

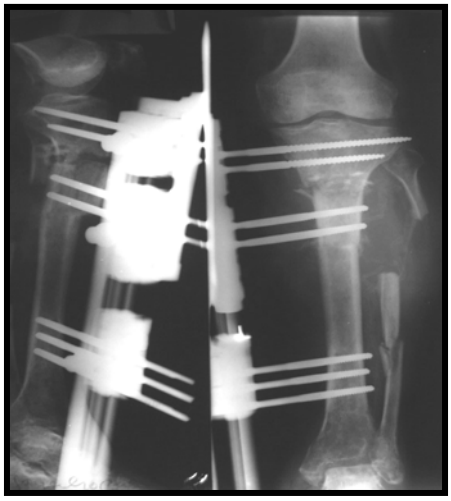
AFTER REMOVAL OF FIXATOR

CLINICAL CASE: RAJKUMAR 35 MALE (MASTER CHART: 3)

INFECTED NON-UNION LEFT TIBIA

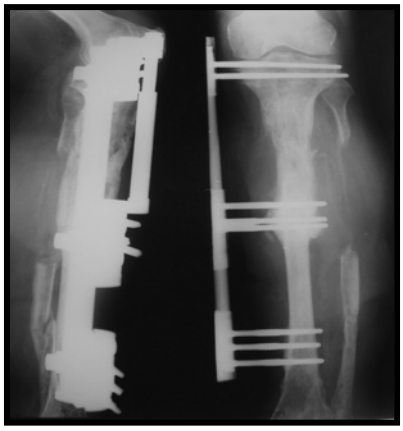


METAL EXIT, DEBRIDEMENT, DOCKING, FIXATOR APPLIED, CORTICOTOMY



DISTRACTION AFTER 6WKS

CONSOLIDATION AT 6 MONTHS



AFTER FIXATOR REMOVAL

RUBEN 32 / M (MASTER CHART NO.11)

INFECTED NONUNION LEFT TIBIA

ON ORTHOFIX FIXATOR FOR 2 MONTHS

CLINICAL PHOTO

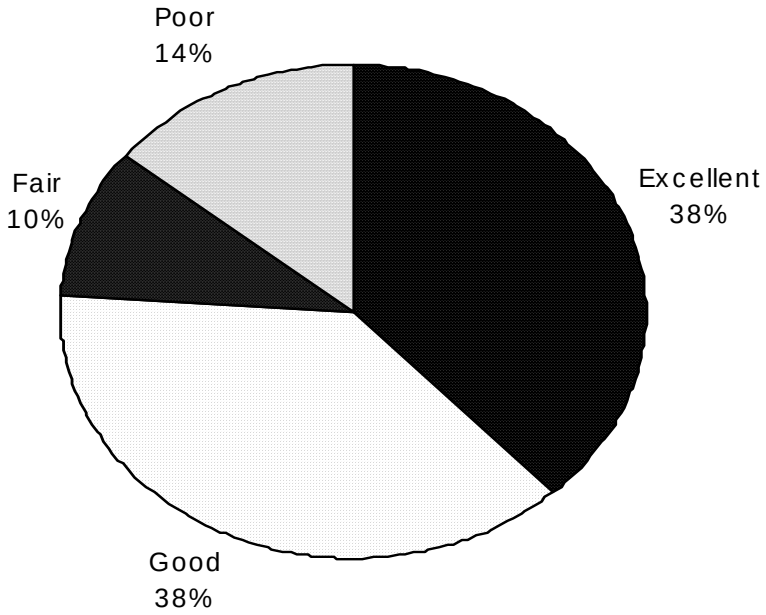
GOOD CONSOLIDATION AFTER 6 MONTHS

REHABILITATION:

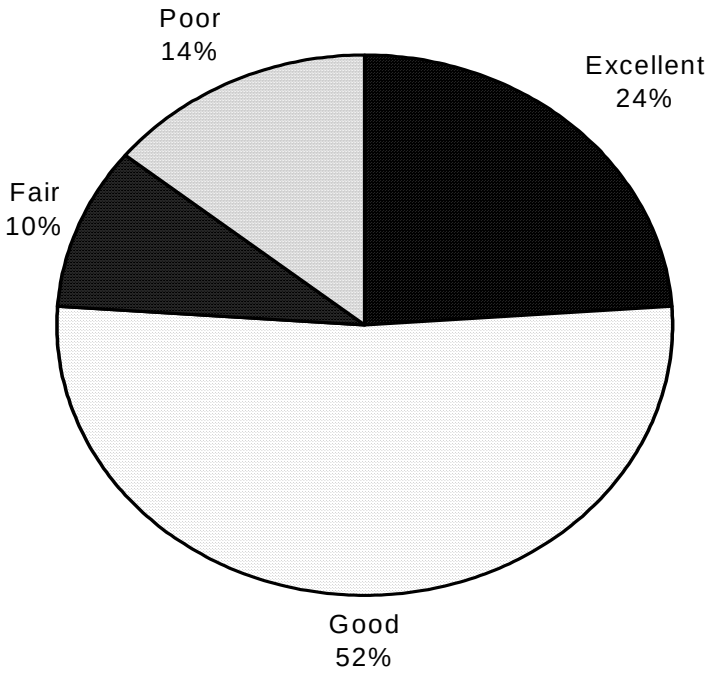
PATIENTS UNDERGOING PHYSIOTHERAPY

FUNCTIONAL CAST BRACE/ SPLINT/POP CAST WORN AFTER REMOVAL OF FIXATOR

BONY RESULTS



FUNCTIONAL RESULTS



COMPLICATIONS:

EQUINUS DEFORMITY AND KNEE STIFFNESS

PIN TRACT INFECTION

MALUNION

SHORTENING

PERSISTENT INFECTION AND NON-UNION

DISCUSSION

The overall goal in the reconstruction of an infected un united long bone fracture involves more than control of infection and includes creation of a healed aligned and drainage free limb which is **functionally better** than that which could have been achieved by **amputation and prosthetic fitting**. Several factors must be considered in reconstruction of bone including the patient's age, metabolic status, mobility of the foot and ankle, integrity of neuro-vascular structures and importantly the patient's motivation. The extent of bony debridement is defined by the presence of punctate bleeding points observed. The **non union site must be resected** as it is better to substitute a poorly biological atrophic bone area with two bone surfaces of good quality modeled in such a way as to allow for easy stabilization under compression.

The decision to proceed with the reconstruction is based on not only the surgeon's ability to restore a functional limb but also the duration anticipated for treatment and the anticipated residual disability. Through wound debridement and removable of the doubtful bone and soft tissues to keep the area totally devoid of non viable tissue is essential

for achieving bony union. In our study 3 cases had persistent non-union, all these cases had **persistent infection** in spite of taking antibiotics. For two patients change of plan of management towards Ilizarov was considered and in another patient repeat debridement, excision of all the necrotic bone and supracondylar corticotomy was planned for bone lengthening.

The patient must be **cooperative** and understand the length of time the frame has to be worn and complications requiring pin revision are a probability. In elective situations the patients can be made to meet other patients who has gone through this process, have preoperative teaching and elect this treatment protocol. Patients may accept these techniques better when they have chosen it as an elective reconstruction rather than when it is inflicted on them.

Patients require adequate nutrition, exercise, and encouragement to stop smoking. Although distraction osteogenesis is associated with marked improvement of the blood supply, good vascularization is necessary to obtain bone healing, especially in patients with infected nonunion. Before the surgery it is necessary to plan the

procedure adequately. As in other series functional results were inferior to bony results. An excellent bone results does not guarantee a good functional result[15]. As to the 11 cases where there was rigidity of ankle/knee, it must be noted that eight were pre existent and 3 were post treatment. The **functional result is affected by the condition of the nerves, muscles, vessels, joints, and to a lesser extent bone.**

The nonunion site united in all but 3 cases out of 21 **(85.7%)**, which is comparable to the study conducted by **Eduardo Garcia et al**[16] in 2004 wherein the bony union result was 86.7%. **Antonio Biasibetti** in his study had a success rate of 93%

Infected nonunion of humerus are rare yet challenging problem to treat. In our study 2 patients with infected nonunion of humerus were treated with hardware removal, debridement and stabilization in compression with external fixator. The resultant shortening, was accepted. There was evidence of good bony union in an average of **5 months (range 4to 6 months)**, which is comparable to the study by **Gualdrini et a**l[22], where the reported union time was 5.5 months. In another study conducted by **Biasibetti.A et al**[3] the union time

was **4 months**. Since the nonunion was in the diaphyseal region in both the cases, and because of the co-operative mobilization exercises carried out by the patients there was not much of impairment of range of movements in shoulder/elbow joints for both the cases. The results were excellent for both functional aspect as well as bony union.

In long-term study of tibial fractures, **Merchant and dietz** [9] determined that **angular deformities** of **10 to 15 degrees** are well tolerated. **Leg length discrepancy** of up to **2.5 cms** does not require any treatment, **5to 6 degrees of tilt** is acceptable. Likewise minimal translation in the mechanical axis is acceptable. (Range of acceptability unknown)

Pin tract infection occurred in 11 out of 21 cases **(52.3%)**, which is comparable to the study conducted by **Gopal.S et al**[20], where the reported pin tract infection was in ten out of 19 cases **(53%)**. In another study by **J.R Coll** the reported pin tract infection was 30%. Hence the rate of pin tract infection remained high in our study.

Bone transport resulted in a **better restoration** of limb **length discrepancy** in lower limbs. Larger bone defects can be tackled with **two level corticotomies**. Our experience is only with single level corticotomy. Some of the patients who had shortening of more than 1 cm of lower limb did not give consent for limb lengthening procedure which was planned after evidence of union at the nonunion site. The mean limb length discrepancy noted in our study was **2.06 cms**. In a study of 26 cases of infected nonunion conducted by **Eduardo et al**[16] the mean limb length discrepancy noted was **2.03cms**. **Bone grafts** can be added, after infection settles at the nonunion site. Graft can also be added to the regenerate site if progression towards consolidation is slow as quoted in the literature[3].

The **Bone healing index (BHI)** [11] in our study was **47.1 days/cm,** which is high when compared with that reported in the literature. Various studies and their reported BHI[14]: **Aldegheri** described 270 lengthening with a mean BHI of **39 days/cm**, **Spanish study** of 261 lengthening had a lowest BHI of **28 days/cm**, **Noonan et al** reported BHI of **49 days/cm.**

The **Monolateral external fixator** is a telescopic device that can be locked for rigid fixation or unlocked to permit load sharing. Even though the cost of the fixator is high, the patients because of the following reasons accept it:

Light weight, patient friendly, day to-day activities can be done easily, Since the pins are **unilateral** it is much more comfortable for the patients, hence joint mobilization can be done with ease. Being rigid[6], early weight bearing can be allowed with the device. Patient themselves can lengthen very easily.

More over **plastic surgery** procedures like cross leg flap, Fascio-cutaneous flap and skin grafting can be done comfortably. Once the patients have been taught about how to do distraction they are advised to come for review once in 15 days to asses the length gained and also to asses the quality of the regenerate. Moreover the fixator (other than the tapered half pins) can be **reused** for another patient provided there is no damage to the apparatus.

The **disadvantages** include the high cost of the system, inability to use the apparatus for correction of infected nonunion with gross deformity, in severe osteoporosis, stabilization very close to a joint, for which Ilizarov fixator could be a better option.

The cost factor has been reasonably managed by the introduction of Indian version of orthofix. Compared with the Ilizarov ring fixator[11] the unilateral external fixator is simpler to apply and better tolerated by the patients. The **learning curve** for implementation of the unilateral fixator is **less steep** than that encountered with the Ilizarov fixator.

CONCLUSION

In this study we conducted, we could achieve a success rate of 86%, giving good **encouraging** results to most of our patients. Hence we conclude that the Indian version of the **monolateral external fixation** system is **effective** and **convenient** method for the treatment of **infected nonunion of long bones.** This can also be used to correct the limb length discrepancies simultaneously, which can arise during the course of the treatment. Patient with poor cooperation are not good candidates for this technique, which requires wearing the frame for a long time, with probably additional secondary surgical procedures.

*The patient's attender donated implant to be used for the patient and in poor patients; the apparatus removed from another patient was reused
(except the tapered half pins)

*No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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S.no	Name	Age	Sex	Type of infection	Contracture	# to nonunion Mos.	Union time mos.	Follow up mos.	Shortening Cms	No. of previous surgeries	Site	Previous treatment	Plastic procedure	Bony procedure	Corticotomy rate 0.25mm 4 times /day	No. Of days	Length gained Cms	Complications
1.	Govindasamy	2o	M	D	Knee	8	4	28	1.5	1	F	ILnail	-	Metal Exit, debridement, Fixator applied, Compression,	-	-	-	Pin tract infection
2.	Doraikannu	42	M	D	Ankle	6	8	20	-	1	T	IL nail	-	Metal Exit, debridement, Fixator applied, Distraction Compression	0.25mm 4 times /day	46	4	Equinus
3.	Rajkumar	35	M	D	-	8	7	21	-	1	T	IL nail	S S G	Metal Exit, debridement, Fixator applied, Distraction compression	0.25mm 4 times /day	42	4	-
4.	Parthasarathy	54	M	D	-	6	6	17	-	1	T	IL nail	S S G	Metal Exit, debridement, Fixator, Distraction compression	0.25mm 4 times /day	53	5	Equinus
.5	Chinnakannu	56	M	A N D	Knee	8	9	19	2	-	F	Native	-	Debridement, Fixator applied, Compression,	-	-	-	Pin tract infection equinus
6.	Praveen	16	M	D	-	5	4	16	2.5	1	F	Plating	-	Metal Exit, debridement, Fixator applied, Compression,	-	-	-	-
7.	Padmavathy	65	F	D	Knee	7	6	18	3	1	F	IL nail	-	Metal Exit, debridement, Fixator applied, Compression,	-	-	-	Pin tract infection
8.	Vinayagam	40	M	Q N D	Ankle Knee	7	8	20	2	-	F	Native		Debridement, Fixator applied, Compression,	-	-	-	Pin tract infection equinus
9.	Ravichandran	29	M	A N D	-	5	6	17	-	-	F	Native	-	Debridement, Fixator applied, Distraction Compression,	0.25mm 4 times /day	58	5	-

S.no	Name	Age	Sex	Type of infection	Contracture	# To nonunion Mos.	Union time mos.	Follow up mos.	Shortening cms	No. of previous surgeries	Site	Previous treatment	Plastic procedure	Bony procedure	Corticotomy rate 0.25mm 4 times /day	No. Of days	Length gained cms	Complications
10.	Anthony muthu	65	M	AND	-	7	4	12	1	1	H	Plating	-	Metal Exit, debridement, Fixator applied Compression,	-	-	-	-
11.	Ruben	32	M	QND	-	4	6	16	<I		T	Native	Skin Graft	Debridement, Fixator applied Compression	-	-	-	Wound Dehiscence
12.	Sathyaraj	16	M	QND	-	4	6	13	-	1	T	POP	Skin Graft	Debridement, Fixator applied Compression, distracti on osteosynthesis	0.25 mm 4 times a day	34	3	Wound Dehiscence
13.	Soorya	19	F	D	Ankle	7	5	19	2		F	Native	-	Debridement, Fixator, compression	-			Pin tract infection
14.	Abdul	50	M	D	Knee	6	5	10	2	-	T	POP	-	Debridement, Fixator applied Compression,	-	-	-	Pin tract infection
15.	Thameen	22	M	D	Ankle	6	-	9	2	1	T	Ext. fixator	SSG Flap	Metal Exit, debridement, Fixator applied Compression,	-	-	-	Equinus NU
16.	Palaniappan	55	M	D	Knee Ankle	12	7	8	3	1	F	External fixator	SSG Flap	Metal Exit, debridement, Fixator applied Compression,	-	-	-	Pin tract infection
17.	Sarala	45	F	D		5	6	10	2	1	H	Plating	-	Metal exit debridement, Fixator applied Compression,	-	-	-	-
18.	Veerappan	25	M	D	Knee Ankle	5	-	12	3	1	F	K-nail	SSG	Metal exit debridement, Fixator applied Compression,	-	-	-	Pin tract infection NU

S.no	19.	20.	21.
Name	Sudhakar	Sekar	Gnaam
Age	30	38	27
Sex	M	M	M
Type of infection	D	QND	D
Contracture	Knee Ankle	Knee	-
# to nonunion Mos.	4	7	5
Union time mos.	-	4	6
Follow up mos.	15	6	14
Shortening Cms	3	1	2
No. of previous surgeries	1	1	-
Site	F	F	F
Previous treatment	Ext. fix.	Plating	Native
Plastic procedure	SSG	-	-
Bony procedure	Metal Exit, debridement, Fixator applied Compression,	Metal exit, debridement, Fixator applied Compression	Debridement, Fixator applied Compression
Corticotomy rate 0.25mm 4 times /day	-	-	-
No. of days	-	-	
Length gained cms	-	-	
Complications	Pin tract Infection NU	Pin tract infection	Pin tract infection

AND-Active non-drain, D-Drain, QND-Quiescent non drain, F-Femur, T-Tibia, H-Humerus NU-Nonunion

MASTER CHART

S.no	Name	Age	Sex	Union	Infection	Deformity after union	Shortening Cms	Grade	Limp	Pain	Rigid	Soft tissue Dystrophy	Inactivity	Grade
1	Govindasamy	20	M	+	-	7* varus	1.5	E	+	-	-	+	-	G
2	Doraikannu	42	M	+	-	-	-	E	-	-	-	_-	-	E
3	Rajkumar	35	M	+	-	-	-	E	-	+	-	+	-	G
4	Parthasarathy	54	M	+	-	-	-	E	-	-	-	-	-	E
5	Chinnakannu	56	M	+	-	10*varus	2	G	+	-	+	+	-	F
6	Praveen	16	M	+	-	7*varus	2.5	E	+	+	-	-	-	G
7	Padmavathy	65	F	+	-	10*Valgus	3	F	+	-	+	_	-	G
8	Vinayagam	40	M	+	-	14*valgus	2	G	+	-	+	+	-	F
9	Ravichandran	29	M	+	-	-	-	E	-	+	-	+	-	G
10	Ruben	32	M	+	-	-	<1	E	-	-	-	-	-	E
11	Sathyaraj	16	M	+	-	10*valgus	-	G	-	+	-	+	-	G
12	Soorya	19	F	+	-	6*valgus	2	E	+	+	-	-	-	G
13	Abdul	50	M	+	-	10*valgus	2	G	+	+	-	-	-	G
14	Thameen	22	M	-	+	-	+	P	+	+	+	+	+	P
15	Palaniappan	55	M	+	-	10*varus	3	F	+	-	+	-	-	G
16	Veerapan	25	M	-	+	-	+	P	+	+	+	+	+	P
17	Sudhakar	30	M	-	+	-	+	P	+	+	+	+	+	P
18	Sekar	38	M	+	_	7*valgus	1	E	+	-	+	-	-	G
19	Gnanam	27	M	+	-	10* Varus	2	G	+	+	-	-	-	G